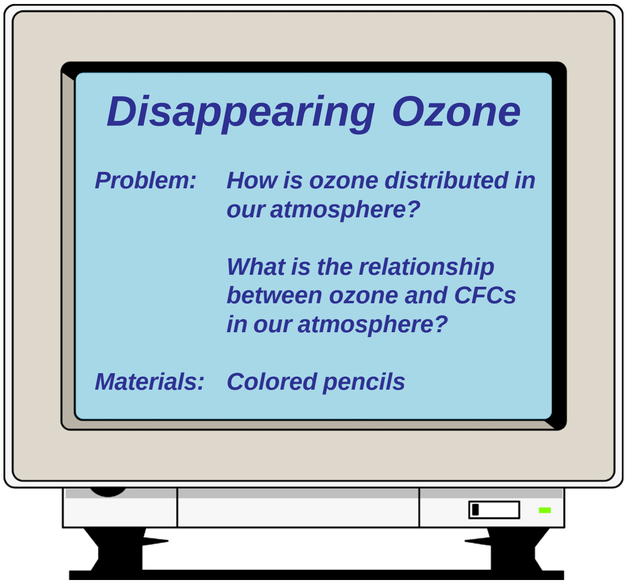
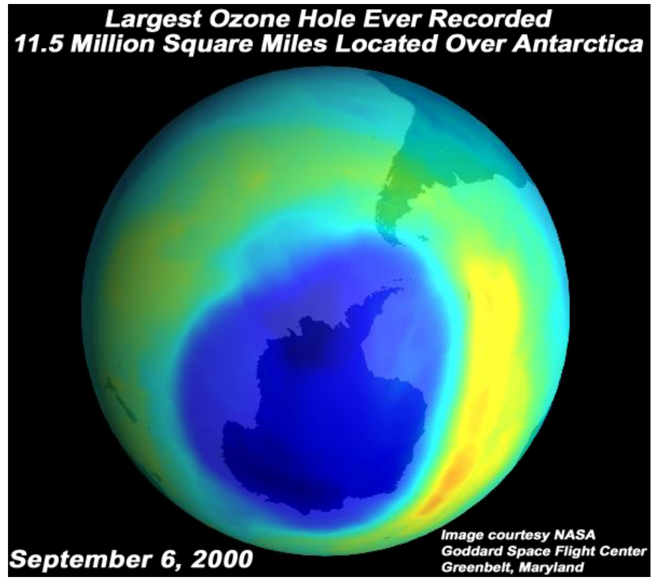




Background

If you are reading this information, you must be breathing. And if you are breathing, you just inhaled ozone! Ozone is an atmospheric gas that is all around us. What is ozone? What does it do in our atmosphere?

Ozone is an oxygen molecule that contains three atoms of oxygen (O_3) that are held together in the shape of the letter “V”. Although ozone is all around us in the air, it is rare. In every million molecules of air, fewer than ten of the molecules are ozone.

Nitrogen and oxygen make up most of the molecules of air that we breathe. Unlike ozone however, the form of oxygen that we are most familiar with contains only two atoms of oxygen (O_2). Our bodies inhale O_2, and fire burns only in O_2. But what does ozone do in our atmosphere?

Close to Earth’s surface, in the layer of our atmosphere called the troposphere, ozone plays a destructive role. Not only is ozone one of the components of unsightly smog that hovers above many cities around the world, but it readily reacts with other molecules.

In high concentrations, it can cause severe damage to plants and animals. Also, ozone can contribute to greenhouse warming. Ozone in our troposphere causes enough harm so that governments are attempting to decrease its levels.

In contrast, ozone in our stratosphere, the layer of our atmosphere above the troposphere, plays quite a different role. Although smog ozone and stratospheric ozone are the same molecule, in the stratosphere ozone actually protects plants and animals by absorbing harmful ultraviolet radiation from the sun.

This thin layer of ozone is a natural part of the Earth's stratosphere that acts like the lenses in sunglasses to filter harmful rays before they reach the Earth's surface. Unfortunately, this protective ozone is being threatened by some of the chemical pollutants that humans have been releasing into the atmosphere.

In the early1970's, researchers discovered that nitrogen, hydrogen, and chlorine compounds, which humans have added to our atmosphere, destroy ozone in the stratosphere faster than nature replaces it.

One group of these compounds, called Chlorofluorocarbons (CFCs), contains chlorine and is used as a coolant for refrigerators and air conditioners, as well as for products such as beverage cups and insulation for houses. Chlorofluorocarbons help to break apart ozone molecules.

Refer to Figure 3.1 on the opposite page for a step-by-step description of the ozone destruction process in the atmosphere.

As shown in Figure 3.1, researchers calculate that each chlorine atom can destroy many thousands of ozone molecules. This decrease in ozone levels allows more ultraviolet light to reach the Earth's surface, which causes an increased risk of skin cancer and cataracts in humans. In addition, the increased ultraviolet light at the surface causes harm to food crops and other plants and animals.

Researchers now know that each Southern Hemispheric winter there is an pronounced decrease in ozone concentrations, sort of an ozone "hole," that grows large over Antarctica and now extends up to the southern tip of South America. This is shown in the graphic on the right-hand side of Page 1 of this activity. The ozone levels then return to near normal as the Southern Hemispheric summer approaches.

The same process happens to a lesser degree during winter in the Northern Hemisphere. This phenomenon, which appeared in the late 1970s, coincides with the human use of chlorine compounds.

Governments have responded to this threat of disappearing ozone. In September 1987, representatives from around the world met in Montreal to forge an unprecedented agreement called the Montreal Protocol. Countries agreed to keep their production of CFCs at 1986 levels, then cut production and CFC use in half over the next ten years.

Since then, countries have agreed to phase out ozone-destroying compounds except for essential uses. Furthermore, industries have been successful in finding many ozone-friendly substitutes for CFCs.

This worldwide accord represents a major breakthrough for international relations. For the first time, nations around the world have joined together to protect the Earth for future generations.

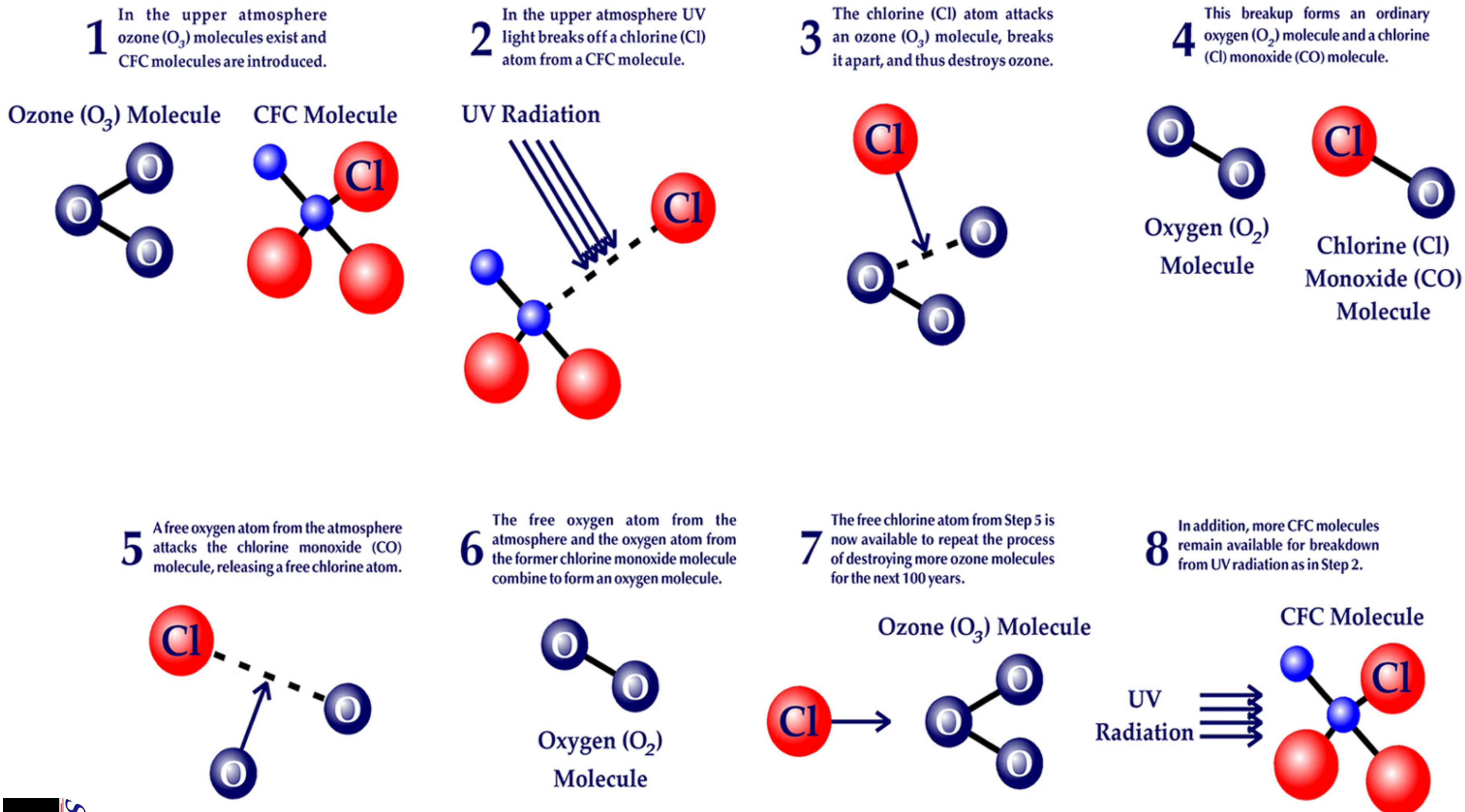


Figure 3.1. Chlorofluorocarbon (CFC) Ozone Destruction Process

Procedure

Part A

The data for this activity were collected at NOAA's Climate Monitoring and Diagnostics Laboratory, Boulder, Colorado.

The troposphere is the layer of our atmosphere closest to the Earth's surface. It is the layer that sustains life.

Above the troposphere rests the stratosphere. As you travel upward in the atmosphere from the Earth's surface - through the troposphere - then the stratosphere - temperature changes.

To identify these two atmospheric layers, complete the following instructions.

1. Using Table 3.1 and the bottom (right) x-axis in Figure 3.2, plot the points corresponding to temperature and altitude. Use a colored pencil to connect the points.

Altitude [Above Earth's Surface] (km)	Temperature (°C)	Ozone Concentration (MPa)	Altitude [Above Earth's Surface] (km)	Temperature (°C)	Ozone Concentration (MPa)
0	12.1	5.01	18	-59.0	10.53
1	6.3	4.70	19	-58.2	13.12
2	5.1	3.98	20	-56.5	12.64
3	-3.1	3.43	21	-54.1	13.77
4	-9.5	2.49	22	-52.9	13.86
5	-17.6	2.20	23	-51.8	13.70
6	-25.7	1.75	24	-51.2	13.18
7	-33.9	1.59	25	-49.0	12.19
8	-41.5	1.65	26	-42.1	12.22
9	-45.1	1.86	27	-42.6	11.68
10	-49.7	2.39	28	-38.8	10.90
11	-49.9	2.47	29	-36.6	9.71
12	-53.8	1.83	30	-35.2	8.37
13	-62.1	1.62	31	-32.0	7.34
14	-67.9	1.57	32	-30.2	6.46
15	-69.9	2.20	33	-27.0	5.32
16	-70.2	2.97	34	-21.3	4.50
17	-64.1	6.27			

Table 3.1. Altitude, Temperature, and Ozone Concentration Data

FYI

Units of Measure for Ozone

One unit used to measure ozone is a **milliPascal (mPa)**. This unit of pressure in the SI system measures the amount of ozone in the atmosphere.

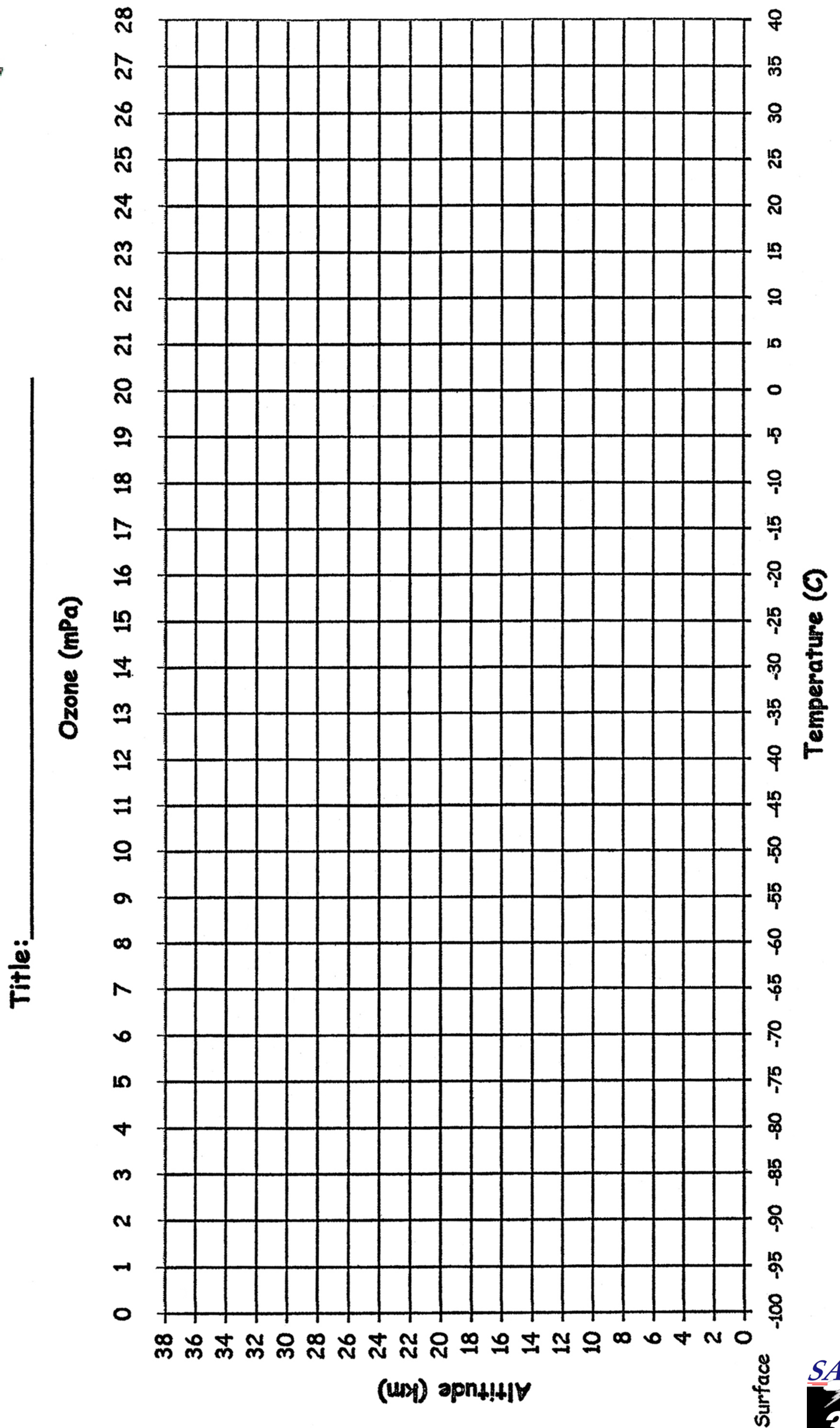

Title:
Ozone (mPa)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
Altitude (km)
38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0
Surface
-100 -95 -90 -85 -80 -75 -70 -65 -60 -55 -50 -45 -40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 40
Temperature (C)

Figure 3.2.

2. The layers of the atmosphere are defined by increasing or decreasing temperature. As you go up in altitude from the Earth's surface, find the point where the temperature stops decreasing.

   Draw a horizontal line across the graph at that point. Label the area below the line the "Troposphere" - label the area above the line the "Stratosphere."

   Like temperature, the amount of ozone changes with increasing altitude. Recall that ozone plays two important but different roles in our lives. Ozone near the surface is a pollutant; whereas, ozone in the Earth's stratosphere protects the Earth from harmful UV rays.

   Therefore, researchers want to know where the different concentrations of ozone are located. They use helium-filled balloons to carry equipment that measures the amount of ozone from the Earth's surface upward through the troposphere into the stratosphere.

3. Using Table 3.1 and the top (left) x-axis in Figure 3.2, plot the points corresponding to the ozone concentration and altitude. Use a different colored pencil to connect the points.

4. Write a title for your graph plotted in Figure 3.2.

Questions

Part A

1. What is ozone?

2. What are CFCs?

3. What is the lowest temperature in °C of the troposphere?

4. What is the highest concentration of ozone in mPa?

5. According to your graph in Figure 3.3, at what altitude in kilometers does the troposphere end?

6. Name the layer of our atmosphere where the highest concentration of ozone exists.

7. How do CFCs get into the atmosphere?

8. Estimate the percent of total ozone on your graph in Figure 3.2 that is located in the troposphere. (Hint: Shade the area between the ozone concentration part of the graph and the y-axis to help visualize the amount of ozone.)

9. Explain how ozone can be both harmful and helpful.

10. List three ways that you, your family, your school and your community might have an effect on the ozone layer.

1. ____________________

2. ____________________

3. ____________________

Procedure
Part B

The data for this part of the activity comes from NOAA's Aeronomy Laboratory in Boulder, Colorado.

What causes ozone to disappear every winter above Antarctica? To test for the suspected culprit, chlorine compounds, researchers first used ground-based instruments and balloons. Their suspicions were confirmed.

Then, researchers sent airplanes into the cold Antarctic sky to gather conclusive data about ozone disappearing over the icy continent. Again, their suspicions were confirmed...The ozone was, in fact, disappearing.

By plotting the following information, you will see the relationship between the amount of chlorine compounds and the amount of ozone over the Antarctic continent. Researchers use information like this to analyze changes in the ozone hole and to investigate possible causes.

Each of the data points listed in Table 3.2 represents an observation for the amounts of ozone and chlorine monoxide, each measured in parts per trillion, at a particular latitude, as observed from a research aircraft flying at high altitude over the Antarctic continent.

Latitude (South of the Equator)	Ozone Concentration (Parts per Trillion [ppt])	Chlorine Monoxide Concentration (Parts per Trillion [ppt])	Latitude (South of the Equator)	Ozone Concentration (Parts per Trillion [ppt])	Chlorine Monoxide Concentration (Parts per Trillion [ppt])
63.0	2473.75	61.65	67.6	2113.00	197.53
63.2	2453.00	69.83	67.8	1903.00	338.08
63.5	2560.75	74.33	68.0	1717.75	426.55
63.7	2498.25	69.15	68.2	2215.25	210.25
63.9	2511.25	74.83	68.4	1766.50	454.88
64.1	2554.25	77.43	68.7	1654.50	552.38
64.3	2564.75	73.43	68.9	1468.75	723.73
64.5	2510.25	77.53	69.1	1107.00	1020.50
64.7	2538.00	83.10	69.3	1037.00	1080.45
64.9	2634.25	83.08	69.5	1016.75	1136.58
65.1	2511.25	80.75	69.7	1008.25	1181.25
65.3	2513.00	85.58	69.9	1010.50	1164.40
65.6	2537.00	90.35	70.1	1008.00	1183.08
65.8	2586.25	100.85	70.3	1025.00	1179.15
66.0	2611.25	99.88	70.6	1036.00	1155.28
66.2	2619.00	95.93	70.8	1050.50	1160.98
66.4	2558.00	104.95	71.0	1062.25	1162.78
66.6	2544.00	100.28	71.2	1073.25	1163.43
66.8	2453.25	110.78	71.4	1076.50	1165.70
67.0	2453.75	116.98	71.6	1080.00	1170.05
67.2	2517.50	108.85	71.8	1083.50	1175.60
67.4	2512.25	109.95			

Table 3.2. Latitude, Ozone Concentation, and Chlorine Monoxide Concentration Data

FYI

Units of Measure for Ozone and Chlorine Monoxide

Here is another unit of measure for chlorine monoxide, as well as ozone. The amount of ozone and chlorine monoxide can be measured in "parts" of a total number. For example, the amount of atmospheric ozone might be 2474 parts per trillion. This means that out of a trillion molecules of air, with all of the various components that make up our air, 2474 molecules are ozone. It would be written as 2474 ppt. This is called a "concentration" of ozone and chlorine monoxide.

The aircraft that measured the ozone and chlorine monoxide flew south at high altitude from Punta Arenas (53°S), on the southern tip of Chile, to the edge of Antarctica (72°S). Refer to Figure 3.3 for a diagram.

Figure 3.3. High Altitude Flights Measuring Ozone

1. Using the data provided in Table 3.2 and the left-hand side of the y-axis (bottom) in Figure 3.4, plot the points corresponding to the ozone concentration and latitude.

   Use a colored pencil to connect the points.

2. Using the data provided in Table 3.2 and the right-hand side of the y-axis (top) in Figure 3.4, plot the points corresponding to the chlorine monoxide concentration and latitude.

   Use a colored pencil to connect the points.

3. Print a title at the top of your graph in Figure 3.4.

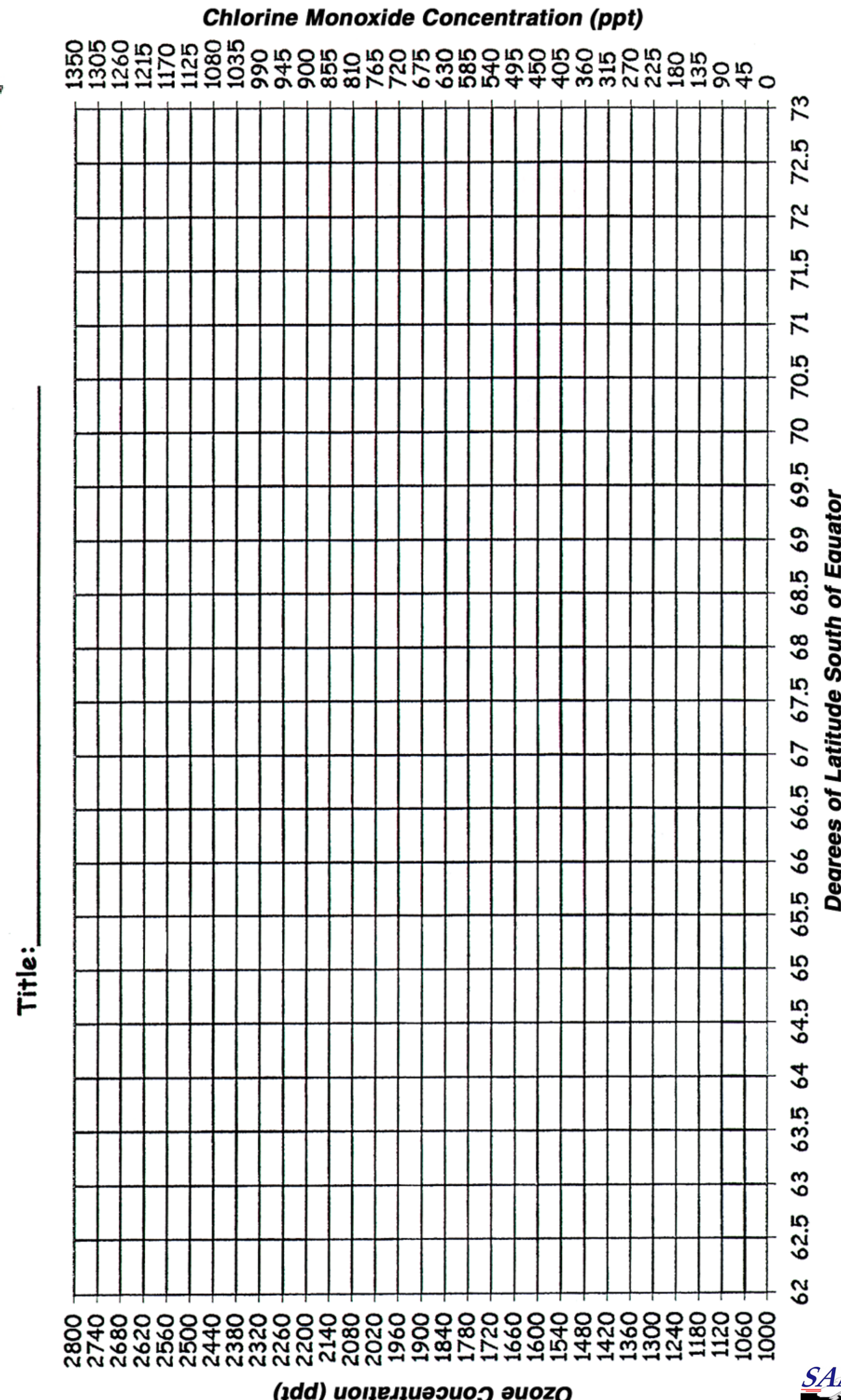


Figure 3.4.

3-11

Questions
Part B

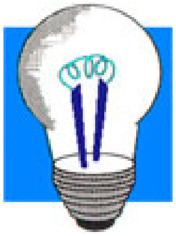
1. What is causing ozone to disappear? Give examples.

2. Why is disappearing ozone a problem?

3. As the aircraft flew from Chile to Antarctica, shown in Figure 3.3, what happened to the ozone and chlorine monoxide concentrations? What does this show about the relation between ozone and chlorine above Antarctica?

4. Describe the Montreal Protocol.

5. Many pieces of the ozone puzzle remain missing. What are some questions that might be answered through scientific investigation?



Conclusion

Review the problem(s) stated on the first page and write a detailed conclusion here.